**AN OCCUPANT SAFETY-RESTRAINT SYSTEM AND
METHOD FOR FULLY DEPLOYING AN AIRBAG
PRIOR TO OCCUPANT CONTACT**

DESCRIPTION

TECHNICAL FIELD

(Para 1)   The present invention relates generally to occupant safety-restraint systems for vehicles, and more particularly to an occupant safety-restraint system for allowing an occupant to contact a fully deployed airbag after the occupant has imparted a maximum load on his seatbelt restraint.

BACKGROUND

(Para 2)   Automotive manufacturers are well known for incorporating various types of airbag systems into their vehicles. These airbag systems typically include one or more crash sensors, which are utilized for detecting a crash event and actuating the deployment of one or more airbags. As is known, these airbags ordinarily are utilized for cushioning an occupant in a crash event and gradually stopping that occupant's momentum over a relatively long period of time. Specifically, the occupant can press into a deployed airbag, compress the gas within the airbag, and force the gas out of the airbag.

(Para 3)   Moreover, automotive manufacturers are also known for incorporating seatbelt restraints into their vehicles. Each seatbelt restraint typically includes a lap belt portion and a shoulder belt portion. Both the lap belt portion and the shoulder belt portion are intended to restrict forward movement of the occupant during a crash event.

(Para 4)   It would be desirable to provide an occupant restraint system that utilizes a variable-output airbag system and a seatbelt restraint system in combination for allowing an occupant to contact a fully deployed airbag after the occupant has imparted a maximum load on his seatbelt restraint.

SUMMARY OF THE INVENTION

(Para 5) The present invention provides an occupant safety restraint system ("OSR system") and method for fully deploying an airbag before an occupant contacts the airbag. In one embodiment, the OSR system includes a seatbelt restraint system, a variable-output airbag system, and a controller coupled to the seatbelt restraint system and the airbag system. The seatbelt restraint system includes a seatbelt restraint for restricting the occupant and a seatbelt-tension sensor for detecting a load or tension in the seatbelt restraint. The controller utilizes the seatbelt load for determining a current seatbelt-tension rate and actuating the airbag system to deploy the airbag at one or more output rates. In other words, the controller can utilize the seatbelt restraint system and the airbag system in combination for regulating the output rate of the airbag system. In that way, the OSR can allow the occupant to contact and press into the airbag substantially proximate to when the occupant has imparted a maximum load on his seatbelt restraint.

(Para 6) One advantage of the present invention is that an OSR system is provided that utilizes a variable output airbag system and a seatbelt restraint system in combination for substantially decreasing the risk of injury to an occupant.

(Para 7) Another advantage of the present invention is that an OSR system is provided that allows a fully deployed airbag to cushion an occupant when the occupant imparts a maximum load on the seatbelt restraint.

(Para 8) Yet another advantage of the present invention is that an OSR system with a variable-output airbag system is provided that can continuously regulate and/or correct the output rate of the airbag system based upon measurements of specific parameters taken during the crash event.

(Para 9) Still another advantage of the present invention is that an OSR system is provided that can safely deploy an airbag for an out-of-position occupant.

(Para 10) Other advantages of the present invention will become apparent upon considering the following detailed description and appended claims, and upon reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

(Para 11)   For a more complete understanding of this invention, reference should now be made to the embodiments illustrated in greater detail in the accompanying drawings and described below by way of the examples of the invention:

(Para 12)   FIGURE 1 is a schematic diagram of an occupant restraint system, according to one advantageous embodiment of the claimed invention; and

(Para 13)   FIGURE 2 is an exemplary chart of an output rate of the occupant restraint system shown in FIGURE 1; and

(Para 14)   FIGURE 3 is a logic flow diagram of a method for operating the occupant restraint system shown in FIGURE 1, according to one advantageous embodiment of the claimed invention.

DETAILED DESCRIPTION OF THE INVENTION

(Para 15)   In the following figures, the same reference numerals are used to identify the same components in the various views.

(Para 16)   The present invention is particularly suited for utilizing a three-point seatbelt restraint and a variable-output airbag system in combination for regulating the output rate of a front airbag. However, various other suitable seatbelt restraints and airbags can be utilized as desired. In this regard, it will be understood that the embodiments described herein employ features where the context permits. Various other embodiments without the described features are contemplated. For that reason, it will be appreciated that the invention can be carried out in various other modes and utilized for other suitable applications as desired.

(Para 17)   Referring to Figure 1, there is shown a schematic diagram of an occupant safety restraint system 10 ("OSR system") integrated within a vehicle, according to one advantageous embodiment of the claimed invention. The OSR system 10 generally includes a seatbelt restraint system 12 ("seatbelt system"), a variable-output airbag system 14 ("airbag system"), and a controller 18 coupled to the seatbelt system 12 and the airbag system 14.

(Para 18)   The airbag system 14 includes an airbag 20 and a variable inflator device 18 for deploying the airbag 20 at two or more output rates. In addition, in this embodiment, the airbag system 14 also includes one or more weight sensors 22 coupled to a vehicle seat. Each weight sensor 22 is utilized for detecting the weight of an occupant in the vehicle seat. The weight sensor sends a weight measurement signal 24' to the controller 18, which utilizes this

data for determining an output rate for the variable-output airbag system 14. The controller 18 utilizes the occupant's weight to search an archived timetable for an estimated amount of time elapsing before the occupant applies a maximum load on his seatbelt restraint.

(Para 19) A person of ordinary skill in the art will understand that the output rates of the airbag system can be predetermined selections based on tests conducted during a specific G-level crash for a specific occupant weight. The test results can be utilized to produce an archived time table, which is stored in the controller's database. The following table provides exemplary test results, which indicate an appropriate output rate for the airbag system 14 during a specific G-level crash.

Occupant Weight (lbs)	Time For Max Belt Load
W < 100	45 ms at 300 lbs
100<W<150	35 ms at 350 lbs
150<W<220	30 ms at 400 lbs
W>220	25 ms at 450 lbs

(Para 20) For example, the weight sensor 22 can detect that the occupant weighs 160 lbs and send this data to the controller 18. Thereafter, the controller 18 can utilize this data and refer to the archived time table for determining that a typical occupant, who weighs between 150 and 200 lbs, may apply a maximum load on the seatbelt restraint 24 30 ms after impact. Thereafter, the controller 18 can calculate a corresponding output rate for actuating the airbag system 14 to fully deploy the airbag 20 within about 30 ms.

(Para 21) Specifically, the controller 18 can utilize the relevant time in the archived table and the volume of the airbag for determining the output rate required to deploy the airbag within that time.

(Para 22) In the embodiment shown in Figure 2, the controller 18 selects a substantially high output rate when the occupant weighs a substantial amount, e.g. 95th percentile individuals. In addition, the controller 18 selects a substantially low output rate when the occupant weighs a relatively low amount, e.g. 5th percentile individuals. In this way, the OSR system 10 allows the occupant to contact a fully deployed airbag 20 substantially proximate to when the occupant imparts a maximum load on his seatbelt restraint 24. This feature is beneficial because the OSR system can distribute the occupant's load between the seatbelt restraint and the airbag substantially proximate to when the occupant is subjected to a load during the crash. For that reason, the OSR system can utilize the airbag system and the seatbelt system in combination for substantially decreasing the occupant's risk of injury.

(Para 23) In another embodiment, the archived time table can be organized and based on the velocity of the vehicle at time t_0, which is the point of impact

during the crash event. In this regard, the OSR system can include a velocity sensor for detecting the vehicle's velocity and transmitting the measurement to the controller. It will be appreciated that tests conducted on the OSR systems can provide suitable output rates based on the velocity of the vehicle. An example of these test results are shown in the following table.

Vehicle Velocity (mph)	Time For Max Belt Load
14<V<18	35 ms
18<V<30	30 ms
V>30	25 ms

(Para 24)   It is further understood that the archived time table can be organized and based on various other suitable parameters besides occupant weight and vehicle velocity.

(Para 25)   The airbag system 14 further includes one or more crash sensors 26 for detecting a crash event and sending a crash signal to the controller 18. These crash sensors 26 are accelerometers or other suitable sensor devices as desired.

(Para 26)   The controller 18 is coupled to the inflator device 18 for actuating the inflator device 18 to deploy the airbag 20 when the controller 18 receives the crash signal from the crash sensor 26. Specifically, the controller 18 can actuate the airbag system 14 with the output rate, which is calculated according to the method generally described above.

(Para 27)   The seatbelt system 12 includes the seatbelt restraint 24 and a seatbelt-tension sensor 28 coupled to the seatbelt restraint 24. The seatbelt-tension sensor 28 is utilized for detecting a load in the seatbelt restraint 24 during the crash event. This sensor 28 is coupled to the controller 18 for sending the load measurements to the controller 18.

(Para 28)   The controller 18 utilizes these load measurements for adjusting the output rate of the airbag system 14 such that the airbag is fully deployed when the occupant has imparted a maximum load on the seatbelt restraint 24 (as detailed in the description for the Figure 3). In this way, the controller 18 can regulate and/or provide real-time correction of the output rate for fully deploying the airbag at a time proximate to when a substantially high load can be distributed between multiple restraint devices. This feature is beneficial because it adjusts the output rate according to circumstances that may not have been accounted for in the original crash tests, which were conducted by the manufacturer for producing the archived time table. In continuation of the previous example, a 160-lb. occupant may apply a maximum load on the seatbelt 35 ms after impact instead of 30 ms after impact because the occupant is substantially reclined or otherwise out-of-position. In that regard

and as detailed in Figure 3, the OSR system 10 can correct the output rate to fully deploy the airbag later than originally expected.

(Para 29) Referring now to Figure 3, there is shown a logic flow diagram of a method for operating the OSR system 10 shown in Figure 1, according to one advantageous embodiment of the claimed invention. In this embodiment, the OSR system 10 utilizes various archived reference tables for regulating the output rate of the airbag system 14. These reference tables are stored within the controller's database and are compilations of data obtained from tests conducted on vehicles having the OSR system 10. This data is organized and based on the weight of the occupant in the vehicle. However, it is contemplated that the reference data can be based on various other kinds of suitable data.

(Para 30) This method commences in step 100 and then immediately proceeds to step 102.

(Para 31) In step 102, one or more weight sensors 22 measure the weight of the occupant in the vehicle seat and transmit the weight measurement signal to the controller 18. This step may be accomplished by utilizing bladders or various other suitable weight sensing mechanisms known in the art. The sequence then proceeds to step 104.

(Para 32) In step 104, the controller 18 utilizes the occupant's weight measurement for determining the output rate of the airbag system 14. As introduced hereinabove, the controller 18 utilizes the occupant's weight measurement to search the archived time table for the estimated amount of time elapsing before the occupant imparts a maximum force on the seatbelt restraint 24. The controller 18 then utilizes the estimated time and the volume of the airbag to calculate an output rate, which allows the airbag system 14 to fully deploy the airbag 20 within the estimated time. For example, the weight sensor 22 may detect that the occupant weighs 160 lbs. The controller 18 can then refer to the archived time table and determine that maximum seatbelt loading can occur 30 milliseconds after the crash event. The controller 18 can utilize the 30 millisecond time period and the known volume of the airbag, e.g. 60 liters, for determining an sufficient output rate for fully deploying the airbag substantially proximate to 30 milliseconds after impact. In this example, the controller 18 can calculate the output rate as two liters per millisecond to fully inflate the 60-liter airbag within 30 milliseconds. Then, the sequence proceeds to step 106.

(Para 33) In another embodiment, steps 102 and 104 are respectively accomplished by detecting the vehicle's velocity and then utilizing the velocity to search an archived time table, which is produced and organized according to the vehicle's velocity. For that reason, the controller sets the initial output

rate of the airbag system based on the vehicle's velocity at impact rather than the occupant's weight. Thereafter, the controller can utilize the estimated time and the known volume of the airbag for calculating an output rate for the airbag system 14.

(Para 34) In step 106, the controller 18 determines whether a crash event has occurred. This step is accomplished by utilizing one or more crash sensors 26, which are coupled to the controller 18. These crash sensors 26 can be accelerometers or various other suitable crash sensors known in the art. If no crash has been detected, then the sequence returns to step 102.

(Para 35) However, if in step 106, the controller 18 determines that a crash event has occurred, then the sequence proceeds to step 108.

(Para 36) In step 108, the controller 18 utilizes the seatbelt-tension sensor 28 for measuring the seatbelt tension at time t_n. It will be appreciated that during the first cycle of operation, time t_n is time t_0 or substantially proximate to when the crash event has been detected by the controller 18. The sequence then proceeds to step 110.

(Para 37) In step 110, the controller 18 utilizes the seatbelt-tension sensor 28 for measuring the seatbelt tension at time t_{n+1}, which is a predetermined amount of elapsed time after the first measurement was taken in step 108. Then, the sequence proceeds to step 112.

(Para 38) In step 112, the controller 18 utilizes the load measurements taken in steps 108 and 110 for determining a current seatbelt-tensioning rate. Specifically, the controller 18 subtracts the first load measurement from the second load measurement and divides the difference by the time elapsed between the tension measurements. However, it is contemplated that the OSR system 10 can utilize various other suitable methods and devices for determining the current seatbelt-tensioning rate. Then, the sequence proceeds to step 114.

(Para 39) In step 114, the controller 18 determines whether the current seatbelt-tensioning rate is greater than a maximum threshold. Specifically, the controller 18 can utilize the occupant's weight measurement and search an archived maximum-threshold table, which is stored within the controller's database, for the corresponding threshold value. It will be appreciated that the data in this table can be produced by tests conducted for a vehicle during a predetermined G-level crash while utilizing an airbag having a predetermined volume. This table is exemplified as follows.

Occupant Weight (lbs)	Max Threshold (lbs/ms)
W<100	6.66
100<W<150	10.00
150<W<220	13.33
W>220	18.00

(Para 40)   In this way, the controller 18 can search the archived maximum-threshold table for determining the maximum threshold and comparing the current seatbelt-tensioning rate to the maximum threshold. If the controller 18 determines that the current seatbelt-tensioning rate is greater than the maximum threshold, then the sequence immediately proceeds to step 116.

(Para 41)   In another embodiment, the controller utilizes the vehicle's current velocity to search an archived maximum-threshold table, which is organized according to the vehicle's velocity. For example, tests on an OSR system can produce the following archived maximum-threshold table.

Vehicle Velocity (mph)	Max Threshold (lbs/ms)
14<V<18	6.66
18<V<30	10.00
V>30	13.33

(Para 42)   In step 116, the controller 18 increases the output rate of the inflator device 18 by a predetermined increment. Then, the sequence proceeds to step 118.

(Para 43)   In step 118, the controller 18 actuates the airbag system 14 to inflate the airbag 20 at the current output rate setting. In the first instance of this cycle, the controller 18 actuates the airbag system 14 to begin inflating the airbag at the current output rate. However, in subsequent cycles, step 118 is accomplished by actuating the airbag system to continue inflating the airbag 20 at the current output rate setting.

(Para 44)   However, if back in step 114 the controller 18 determined that the seatbelt-tensioning rate is less than the maximum threshold, than the sequence proceeds to step 120.

(Para 45)   In step 120, the controller 18 determines whether the current seatbelt-tensioning rate is less than a minimum threshold. Specifically, similar to step 114, the controller 18 can utilize the occupant's weight measurement and search an archived minimum-threshold table, which is stored within the controller's database, for the corresponding threshold value. It is understood that the data in this table can be produced by tests conducted for a vehicle during a predetermined G-level crash while utilizing an airbag with a

predetermined volume. This archived minimum-threshold table is exemplified as follows.

Occupant Weight (lbs)	Min Threshold (lbs/ms)
W < 100	6.33
100<W<150	9.66
150<W<220	13.00
W>220	17.66

(Para 46) In this way, the controller 18 can search the archived rate table for determining the minimum threshold and comparing the current seatbelt-tensioning rate to the minimum threshold. If the controller 18 determines that the current seatbelt-tensioning rate is less than the minimum threshold, then the sequence immediately proceeds to step 122.

(Para 47) In another embodiment, the controller can utilize the vehicle's current velocity to search an archived minimum-threshold table, which is organized according to the vehicle's velocity. For example, tests on an OSR system can produce the following archived maximum-threshold table.

Vehicle Velocity (mph)	Min Threshold (lbs/ms)
14<V<18	6.33
18<V<30	9.66
V>30	13.00

(Para 48) In step 122, the controller 18 decreases the output rate of the inflator device 18 by a predetermined increment. Then, the sequence proceeds to step 118 described above.

(Para 49) However, if in step 120 the controller 18 determines that the current seatbelt-tensioning rate is greater than the minimum threshold, then the sequence proceeds immediately to step 118 described above.

(Para 50) After step 118, the sequence proceeds to step 124. In step 124, the controller 18 determines whether the airbag 20 has been fully deployed. This step can be accomplished by multiplying the output rate for the current cycle by the elapsed time for that cycle. By this function, the controller 18 can determine the volume of gas injected into the airbag during the current cycle. Thereafter, this volume of gas can be added to the volumes of gas injected into the airbag during prior cycles. The controller 18 can then compare the total amount of gas injected into the airbag to the known volume of the airbag. If the calculated amount of gas less than the known volume of the airbag, then the sequence returns to step 108 to begin another cycle of operation. However, if the calculated amount of gas is substantially equally to the known volume of the airbag 20, then the sequence terminates.

(Para 51) While particular embodiments of the invention have been shown and described, it will be understood, of course, that the invention is not limited thereto since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. Accordingly, it is intended that the invention be limited only in terms of the appended claims.